



UNIVERSITI PUTRA MALAYSIA

**GIS-BASED NON POINT SOURCE POLLUTION
MODELLING OF SG. SELANGOR BASIN**

ONG YOU SHU

FK 2002 53

**GIS-BASED NON POINT SOURCE POLLUTION MODELLING OF SG.
SELANGOR BASIN**

By

ONG YOU SHU

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of Requirement for the Degree of Master of Science**

August 2002



To my dearest parents and brother.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment
of the requirement for the degree of Master of Science

**GIS-BASED NON POINT SOURCE POLLUTION MODELING OF SG.
SELANGOR BASIN**

By

ONG YOU SHU

August 2002

Chairman: Adjunct Associate Professor Dr. Noordin Ahmad

Faculty: Engineering

Non Point Source (NPS) pollution is a diffuse pollution and regarded as one of the major pollution affecting the quality of water. It is yet to be taken into consideration in managing the water quality of river basin in Malaysia. Geographic Information System (GIS) is used to study the pollution since the sources and the spread involved spatial characteristic. Sg. Selangor basin has been chosen as the study area. Assessment of NPS pollution was conducted based on three parameters namely Biochemical Oxygen Demand (BOD), Total Nitrogen (TN) and Suspended Solids (SS). Runoff and land use are considered as the major factors contributing to the NPS pollution since NPS pollution travels through land area before reaching the stream network. The generated runoff was based on rainfall data and runoff coefficient. Stream network generation will be produced from digitized topographic maps where threshold values were tested. Expected Mean Concentration (EMC) values, associated with land use were extracted from literatures and research works and used to estimate the loading of pollutants in that

area. Data from two sampling stations operated by the Department of Environment, i.e. 3517605 (upstream) and 3516604 (downstream) were to determine the level of NPS pollution. Annual accumulation of NPS pollutions were determined where the cumulative loadings of pollutants were compared with the computed observed values at the two sampling stations. Results for BOD showed that the differences of computed observed values exceeded generated values by 50.1% at the upstream station and by 9.2% at the downstream station. For SS, there is a 38.9% difference at upstream and 38.6% differences at downstream. However, there was a wide variation in TN results with 67.2% differences in upstream and -39.1% in downstream. These variations are mainly due to limitations that are related to theoretical EMC values.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

**PEMODELAN PENCEMARAN BUKAN PUNCA TITIK DI LEMBANGAN
SUNGAI SELANGOR BERPANDUKAN GIS**

Oleh

ONG YOU SHU

Ogos 2002

Pengerusi: Profesor Madya Bersekutu Dr. Noordin Ahmad

Fakulti: Kejuruteraan

Pencemaran bukan punca titik (NPS) adalah satu pencemaran berbaur dan dianggap sebagai salah satu pencemaran utama yang memberi kesan kepada kualiti air. Ianya masih belum lagi diambil kira dalam menguruskan kualiti air bagi lembangan sungai di Malaysia. Sistem Maklumat Geografi (GIS) telah digunakan dalam kajian ini untuk mengkaji pencemaran ini kerana ciri-ciri pencemar yang melibatkan ruangan. .
Lembangan Sg. Selangor telah dipilih sebagai kawasan kajian. Penilaian terhadap pencemaran NPS telah dijalankan di mana tiga parameter telah digunakan iaitu Keperluan Biokimia Oksigen (BOD), Jumlah Nitrogen (TN) dan Pepejal Terapung (SS). Air larian dan guna tanah dianggap sebagai faktor-faktor utama yang menyumbang kepada pencemaran NPS kerana pencemaran NPS melalui kawasan tanah sebelum sampai ke sungai. Penghasilan air larian adalah berdasarkan data air hujan dan pekali air larian. Penghasilan jaringan sungai daripada pendigitan peta-peta topografi dilakukan dengan menguji nilai-nilai ambang. Nilai Jangkaan Min Kepekatan (EMC) yang

dikaitkan dengan guna tanah diambil dari kajian literatur dan hasil penyelidikan digunakan untuk menganggar kemasukan beban pencemaran di kawasan kajian. Data dari dua stesen pencerapan yang diperolehi dari Jabatan Alam Sekitar iaitu 3517605 (hulu sungai) dan 3516604 (hilir sungai) digunakan sebagai titik penentu untuk pencemaran NPS. Pengumpulan tahunan bagi pencemaran NPS ditentukan dengan membandingkan bebanan pencemaran dengan kiraan data pencerapan pada dua stesen pencerapan tersebut. Keputusan untuk BOD menunjukkan kiraan data pencerapan melebihi nilai yang dihasilkan sebanyak 50.1% di stesen hulu sungai dan sebanyak 9.2% di stesen hilir sungai. Bagi SS, perbezaan sebanyak 38.9% terdapat hulu sungai dan sebanyak 38.6% di hilir sungai. Namun begitu, terdapat jurang yang besar dalam keputusan TN dengan 67.2% di hulu sungai dan -39.1% di hilir sungai. Perbezaan ini adalah disebabkan oleh kelemahan-kelemahan yang kebanyakannya berkaitan dengan nilai EMC digunakan yang berujukan bahan.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my sincere gratitude to the members of my supervisory committee, Adjunct Assoc. Prof. Dr. Noordin Ahmad, Assoc. Prof. Dr. Wan Nor Azmin bin Sulaiman and Assoc. Prof. Kwok Chee Yan for their advice, guidance, encouragement and support throughout the study. I would also like to thank Mr. Ahmad Rodzi Mahmud, my previous supervisor, for his guidance and support in my research.

Gratitude also goes out to the various government departments and private sector for provision of data that have made the outcome of this research successful. They are Department of Irrigation and Drainage, Ampang, Department of Soil Management, Ministry of Agriculture, Alam Sekitar Malaysia Sdn. Bhd., Department of Environment, and WWF Malaysia.

I would also like to express my gratitude to my friends who have give encouragement and ideas to me. They are Tan Chun Knee, Azwan Abdul Aziz, Wong Tai Hong, Audrey Bong, Lai Chin Yin and some others in the lab. My special thanks are expressed to Nyon Yong Chik for his wonderful kindness in giving guidance and provide support in technical part of the research. Gratitude also to Brian Lee and T. E. Goh, thanks for the support in technical part and encouragement.

Last but not least, my gratitude to my parents, brother and my housemates for their encouragement.

I certify that an Examination Committee met on 15th August 2002 to conduct the final examination of Ong You Shu on her Master of Science thesis entitled “GIS-Based Non Point Source Pollution Modelling of Sg. Selangor Basin” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Shattri Mansor, Ph.D.

Associate Professor,
Faculty of Engineering,
Universiti Putra Malaysia
(Chairman)

Noordin Ahmad, Ph.D.

Adjunct Associate Professor,
Faculty of Engineering,
Universiti Putra Malaysia
(Member)

Wan Nor Azmin Sulaiman, Ph.D.

Associate Professor,
Faculty of Science and Environmental Studies,
Universiti Putra Malaysia
(Member)

Kwok Chee Yan

Associate Professor,
Faculty of Engineering,
Universiti Putra Malaysia
(Member)



SHAMSER MOHAMAD RAMADILI, Ph.D.

Professor/Deputy Dean,
School of Graduate Studies,
Universiti Putra Malaysia.

Date: 17 OCT 2002

This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the supervisory committee are as follows:

Noordin Ahmad, Ph.D.

Adjunct Associate Professor,
Faculty of Engineering,
Universiti Putra Malaysia
(Chairman)

Wan Nor Azmin Sulaiman, Ph.D.

Associate Professor,
Faculty of Science and Environmental Studies,
Universiti Putra Malaysia
(Member)

Kwok Chee Yan

Associate Professor,
Faculty of Engineering,
Universiti Putra Malaysia
(Member)


AINI IDERIS, Ph.D.

Professor/Dean,
School of Graduate Studies,
Universiti Putra Malaysia.

Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for equations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



ONG YOU SHU

Date: 21/10/2002

TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	vii
APPROVAL	viii
DECLARATION	x
LIST OF TABLES	xiii
LIST OF FIGURES	xiv
LIST OF ABBREVIATIONS	xvi
 CHAPTER	
 I INTRODUCTION	 1
1.1 Introduction	1
1.2 Non Point Source Pollution in Malaysia	3
1.3 Problem Statement	3
1.4 Objectives of the Study	5
1.5 Overview of the Thesis	6
 II LITERATURE REVIEW	 7
2.1 Definition of Non Point Source (NPS) Pollution	7
2.2 NPS Pollution Models	9
2.2.1 Hydrological Simulation Program-FORTRAN (HSPF)	10
2.2.2 Agricultural Non Point Source (AGNPS)	11
2.2.3 Areal Non Point Source Watershed Environment Response Simulation (ANSWERS)	13
2.2.4 Soil Water Assessment Tool (SWAT)	14
2.2.5 Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS)/ Groundwater Loading Effects of Agricultural Management Systems (GLEAMS)	16
2.3 NPS Pollution Parameters	18
2.3.1 Water Quality Parameters	18
2.3.1.1 Total Nitrogen (TN)	19
2.3.1.2 Suspended Solids (SS)	19
2.3.1.3 Biochemical Oxygen Demand (BOD)	20
2.3.2 Land Use Classification	20
2.3.3 Expected Mean Concentration (EMC)	21
2.4 Geographic Information System (GIS)	23
2.5 GIS in Assessing NPS Pollution	25
2.6 Digital Elevation Model (DEM)	28
2.6.1 Resolution of DEM	28
2.6.2 Determination of Flow Direction	30



III	METHODOLOGY	34
3.1	Introduction	34
3.2	Study Area	37
3.3	Data Description	41
3.3.1	Conversion of Spatial Data	41
3.4	Generation of Stream Network	44
3.4.1	Burning of Digital Stream Network	50
3.5	Rainfall-Runoff Analysis	52
3.6	Expected Mean Concentration Values	57
3.7	Pollutants Loading Assessment	60
3.8	Accumulative Pollutants Loading Assessment	63
IV	RESULTS AND DISCUSSION	66
4.1	Generation of Stream Network	66
4.2	Rainfall-Runoff Analysis	79
4.3	Accumulative Pollutants Loading Assessment	82
4.4	Limitations of the Assessment	91
V	CONCLUSION	93
5.1	Overall Conclusion	93
5.2	Recommendations	96
	REFERENCES	98
	APPENDIX A	103
	APPENDIX B	109
	BIODATA OF THE AUTHOR	115

LIST OF TABLES

Table		Page
3.1	Background information on Sg. Selangor basin.	38
3.2	Data used in the study.	41
3.3	Runoff coefficients based on land use categories.	53
3.4	Rainfall stations and the total annual rainfall.	54
3.5	EMC values (mg/l) based on land use.	58
4.1	The differences between the digitized and the generated stream network in length (km) and percentage based on the 250 cells as threshold values.	69
4.2	The differences between the digitized and the generated stream network in length (km) and percentage based on the 200 cells as threshold values.	70
4.3	The differences between the digitized and the generated stream network in length (km) and percentage based on the 150 cells as threshold values.	70
4.4	The differences between the digitized and the generated stream network in length (km) and percentage based on the 100 cells as threshold values.	71
4.5	The differences between the digitized and the generated stream network in length (km) and percentage based on the 50 cells as threshold values.	71
4.6	The linear distance between generated stream network from the digitized stream network in meter.	78
4.7	Water quality data from DOE (mg/l) for the year 1994.	84
4.8	Conversion of the water quality data from DOE for the year 1994.	85
4.9	Comparison of generated and observed for NPS pollution at two stations.	88

LIST OF FIGURES

Figure		Page
2.1	Effect of First Flush on shapes of Pollutograph and Loadograph.	22
2.2	Inter-storm variation of Pollutographs and EMCs.	23
3.1	The outline of the methodology.	36
3.2	Sg. Selangor basin and the study area.	39
3.3	The land use map of the study area.	43
3.4	TIN of the study area.	45
3.5	DEM of the study area in 20m cell size.	46
3.6	Processing of Digital Elevation Data. (a) the eight pour point model; (b) a grid of elevation values; (c) flow direction grid; (d) flow accumulation grid.	47
3.7	The generated stream network using 250 cells threshold values was overlaid with the digitized stream network.	49
3.8	The Burn-in DEM of study area.	51
3.9	Isohyet map produced through interpolation using Spline method.	55
3.10	Map calculator used in computing runoff grid.	56
3.11	EMC of BOD .	58
3.12	EMC of SS.	59
3.13	EMC of TN.	59
3.14	Map calculator used to compute loading of pollutant.	61
3.15	Loading of BOD.	61
3.16	Loading of SS.	62
3.17	Loading of TN.	62
3.18	Flow direction of the study area.	64
3.19	Map Calculator dialog box to compute the accumulation of pollutant.	65
4.1	The generated stream network overlaid with the digitized stream network for the 200 cells as threshold values.	67
4.2	The generated stream network overlaid with the digitized stream network for the 150 cells as threshold value.	68
4.3	The generated stream network overlaid with the digitized stream network for the 100 cells as threshold values.	68
4.4	The generated stream network overlaid with the digitized stream	

	network for the 50 cells threshold values.	69
4.5	The percentage differences of digitized versus generated stream network in length for threshold of 250 cells.	72
4.6	The percentage differences of digitized versus generated stream network in length for threshold of 200 cells.	73
4.7	The percentage differences of digitized versus generated stream network in length for threshold of 150 cells.	73
4.8	The percentage differences of digitized versus generated stream network in length for threshold of 100 cells.	74
4.9	The percentage differences of digitized versus generated stream network in length for threshold of 50 cells.	74
4.10	The percentage of differences in total length of digitized versus generated stream network based on threshold values of flow accumulation.	76
4.11	Ten random samplings taken for “fit” test.	77
4.12	The comparison between 50 cells and 100 cells threshold values for the generated stream network in linear distance from the digitized stream network.	78
4.13	Runoff grid of the study area.	81
4.14	Accumulation of SS.	83
4.15	Zoom-in view of two sampling points taken from DOE.	84
4.16	Percentage differences for BOD.	89
4.17	Percentage differences for TN.	89
4.18	Percentage differences for SS.	89
4.19	Relative accuracy and reliability of hydrologic models of diffuse pollution. Accuracy and reliability decreases with the increased complexity and size of the modeled system.	90

LIST OF ABBREVIATIONS

AGNPS	Agricultural Non Point Source
ANSWERS	Areal Non Point Source Watershed Environment Response Simulation
BMP	Best Management Practices
COD	Chemical Oxygen Demand
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems
DEM	Digital Elevation Model
DID	Drainage and Irrigation Department
DOA	Department of Agriculture
DOE	Department of Environment
EIA	Environmental Impact Assessment
EMC	Expected Mean Concentration
EPA	Environmental Protection Agency
GIS	Geographic Information System
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems
HSPF	Hydrological Simulation Program-FORTRAN
NPS	Non Point Source
SWAT	Soil Water Assessment Tool
TIN	Triangulated Irregular Network
USLE	Universal Soil Loss Equation



CHAPTER I

INTRODUCTION

1.1 Introduction

Water resources especially freshwater are very important and precious to human being. Availability of freshwater resources can be obtained from groundwater or surface water such as rivers, lakes or ponds. Rivers in Malaysia are considered as the main water supply for its population and economic usage. The upstream river water can be used for hydropower generation and water-based recreation and downstream river water can be used for irrigation, municipal uses and waste dilution (Uzir, 1993). In Malaysia, the main usage of water (in 1996) is for irrigation (9.0 billion m³), domestic and industrial water supply (2.6 billion m³) and for hydropower generation (1590 MW) while the minor usage includes breeding and cleaning for fisheries and livestock (Neo, 1996).

Freshwater, which is the key component of the Earth's hydrosphere, is needed for all aspects of life. However the scarcity, gradual deterioration and aggravated pollution of freshwater resources in many world regions are becoming increasingly apparent (Thompson and Hollis, 1997). Managing the water resources to mitigate the pollution level in the rivers requires incorporation of all relevant technical and non-

technical considerations. This can be seen in the river basin management in many developing countries including Malaysia, which is at present carried out by a number of organizations with minimal coordination among them (Nyon, 1999). Hence, integrated river basin management needs to be implemented to provide a sustainable development.

Depleting freshwater resources especially from the rivers are mainly due to pollution from non point source. Non point source pollution is caused by runoff water from rainfall that results in soil surface erosion. The sediment may end up in river or lakes or ponds before flowing towards the sea. It is often difficult to detect the exact location where it happens.

In the process of achieving sustainable development, advances in computer technology have provided useful tool in working towards the goal. Information from various agencies needs to be compiled and gathered to formulate a proper planning. Geographic Information Systems (GIS) is one of the tools that can be used to solve problems which are related to environment such as non point source pollution. It can provide database management, tools, visualization, simulation and assessment models. It also supplies open and unclouded information to generate dependence and a collaboration among all parties involved in river basin management (Nyon, 1999).

1.2 Non Point Source Pollution in Malaysia

Malaysia, as a developing country, has undergone very rapid development with subsequent population growth, urbanization, expansion of agriculture, mining and logging activities, and industrialization. These changes have caused complex environmental problems and the most affected natural resource is water (Yeo, 1999). Due to the rising concern over the degradation of river water quality in Malaysia, monitoring of water quality in Malaysia was conducted by the Department of Environment since 1970s. From 1995, Alam Sekitar Malaysia Sdn Bhd took over the monitoring to continue the effort of maintaining the river water quality (ASMA, 2000).

In Malaysia, emphasis has been put on point source pollution because this pollution causes great impacts on the ecosystem. Controlling of point source pollution is also much easier as “polluter-pay-principle” is applicable. As for non point source pollution, it is still new in terms of number of studies that have been conducted. Therefore, it is difficult to acquire comprehensive information regarding the pollution as this kind of studies need long term. In the past, studies (Loh, 1999; Yeo, 1999) have been done on river water quality that is related to land use activities. Indirectly, this is also related to non point source pollution as the land use is one of its main parameters.

1.3 Problem Statement

As its name implies, non point source pollution is not easily monitored at the point of origin and contaminants are not generally traceable to an exact source. It usually occurs sporadically, and is often correlated with climatic events. Most of the

contribution to water quality degradation is due to non point source, which appears to be equal or exceed those from point sources, often by substantial margin (Hall, 1975). Even the best intentions to have multi-million ringgit water clean up programme would not be a success without the understanding of non point source pollution. This requires the relevant parties to reconsider for a better management plan.

Non point source pollution is produced by the transport by runoff of constituents from diffuse sources on the land to streams (Olivera, 1995). According to Huber (1993), land use has a strong influence only on the amount of runoff (volume of water per unit time), while its effect on the runoff concentration (mass of pollutant per unit volume of water) is less important. Still, land use affects the pollutant load (mass of pollutant per unit time) when the runoff increased. Many methods that have been produced in modelling non point source pollution according to the land use that involved. For examples, the AGNPS model is used for agricultural areas, the USLE method is used for measuring soil loss or erosion, GLEAMS method used for groundwater loading effects from agriculture management systems and etc. Due to the difficulty of obtaining accurate data in the required amount to generate pollutographs (concentration-time plots) or loadographs (mass-time plots), non-point source pollution is commonly represented by the Event Mean Concentration. In this study, Expected Mean Concentration (EMC) was used to represent Event Mean Concentration as it is taken from literature-based and the concentration was to be expected as it is. This method was used as it requires only pollutants concentration parameters based on land use category. In Malaysia, there are no local EMC values available at the moment to be used in

modelling non point source pollution. However, EMC values have been recommended by DID to be used in estimating pollutant loading in river basin. Hence, the hypothesis of this study is EMC is applicable in estimating loading of pollutants.

Modelling of a river basin can be achieved when the right model been applied and there are enough basic data and correct parameters used. With data such as contour, spot height, rainfall and etc., these data can be interpolated and manipulated using GIS to do modelling. Parameters such as the runoff coefficients and EMC values will affects the model that been produced using GIS. As GIS is able to analyse and display the results of the processing, the effects of the parameters used in modelling can be seen. In Malaysia, GIS is yet to be applied in this area as GIS application in this field has not been fully utilized.

1.4 Objectives of the Study

With the current management of river basin in Malaysia where only point source is taken into consideration, there is a pressing need to study the non point source pollution to complete the overall view of the river water quality. GIS will be used as a modelling tool in assessing non point source pollution. The objectives of this study are:-

- a) to find the most suitable grid cell resolution to generate stream network.
- b) to assess the runoff generated from land use and rainfall parameters.
- c) to assess the efficiency of non point source pollution modelling using Expected Mean Concentration (EMC) method.

1.5 Overview of the Thesis

The first chapter highlights the introduction of non point source pollution and the objective of the study. Literature review of the non point source pollution models and the use of GIS in non point source pollution modelling were mentioned in Chapter II. Chapter III describe the methodology of the study to produce the accumulation of non point source pollution. Description on the study area and the data used will also be mentioned in this chapter. The results and analysis of the process are covered in Chapter IV. The discussion of the results and the limitations of the study will also be mentioned in Chapter IV. Finally, conclusion and recommendations on the study are given in Chapter V.

CHAPTER II

LITERATURE REVIEW

2.1 Definition of Non Point Source (NPS) Pollution

Non point source (NPS) water pollution can be defined as a diffuse input of substances into receiving water that negatively impacts the water's beneficial uses. These substances include, but are not limited to, sediments, nutrients, bacteria, oxygen-demanding materials, heavy metals, and trace organics (Reinelt et al., 1988). The Environmental Protection Agency (EPA) defines the NPS pollution as caused by rainfall or snowmelt moving over and through the ground (EPA, 1997). As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. These pollutants include:

- Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas;
- Oil, grease, and toxic chemicals from urban runoff and energy production;
- Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks;

- Salt from irrigation practices and acid drainage from abandoned mines;
- Bacteria and nutrients from livestock, pet wastes, and faulty septic systems;

Assessment of NPS pollutants is a complex; multidisciplinary environmental problems that encompasses physical and chemical processes that occur across disparate spatial and temporal scales. Moreover, NPS pollutants are spread over large areas in relatively low concentrations, and their detrimental environmental health-related effects are chronic rather than acute. Nevertheless, they are of greater environmental concern than point source pollutants because they are ubiquitous and the task of cleanup is costly and nearly impossible to accomplish (Loague et al., 1998).

Some criteria had been developed by Churchill (1975) which described NPS pollution as follows:-

- i. NPSs enter the receiving waters in a diffuse manner.
- ii. They are intermittent.
- iii. The pollutants arise over an extensive area of land and are in transit over land before they enter navigable waters.
- iv. NPS pollutants generally cannot be monitored readily at their point of origin and are not always traceable to their exact source.
- v. Their prevention or control must be directed at a site-specific management or conservation practice.
- vi. Compliance monitoring for NPSs is conducted on land rather than on water.